Robust Multivariate Approaches for Developing Ecological Indicators to Classify Landscapes on a Military Disturbance Gradient

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A SERDP Research Project

- **Strategic Environmental Research and Development Program**
- **Development of Ecological Indicator Guilds for Land Management**
- **5 Year Project**
- **Sponsored By:**
  - **Department of Defense**
  - **Department of Energy**
  - **Environmental Protection Agency**

Research Project Rationale

Management of Military Training/Testing Lands

- Training sustainability
- Ecosystem maintenance and sustainability
- Long-term productivity
- Multiple-use decisions and requirements
- Conditions & Trends in Natural Resources
- Timing and success of restoration efforts
- Environmental monitoring
- Legal mandates

Technical Objective

Develop Ecological Indicators To:

- Quantify habitat condition and trends
- Track and monitor ecological changes
- Provide early-warning or threshold detection
- Provide guidance for land managers based on ecological realities and statistical rigor

Research Project Setting

- **Fort Benning, Georgia**
  - **Fall Line–Sandhills Physiography**
  - **Transition zone: Piedmont – Coastal Plain**
- **9 Research Sites in Two Watersheds**
  - **Mixed Pine/Hardwoods, Sandy Loam Soils**
  - **Agricultural Land-Use pre 1940s**
  - **Disjunct Landscape Disturbance Gradient**
- **3 Sites in each "Disturbance Class"**
  - **Bonham Creek: 2 pairs of Low, Med, High**
    - **L1, L2 - M1, M2 - H1, H2**
  - **Sally Branch: 1 pair of Low, Med, High**
    - **L3 - M3 - H3**

Site Selection Based on a Disjunct Landscape Disturbance Gradient

3 sites selected in each disturbance

High

Current mechanized-in training activities

H3

H1

Medium

Past training activities
Current foot traffic

M3

M1

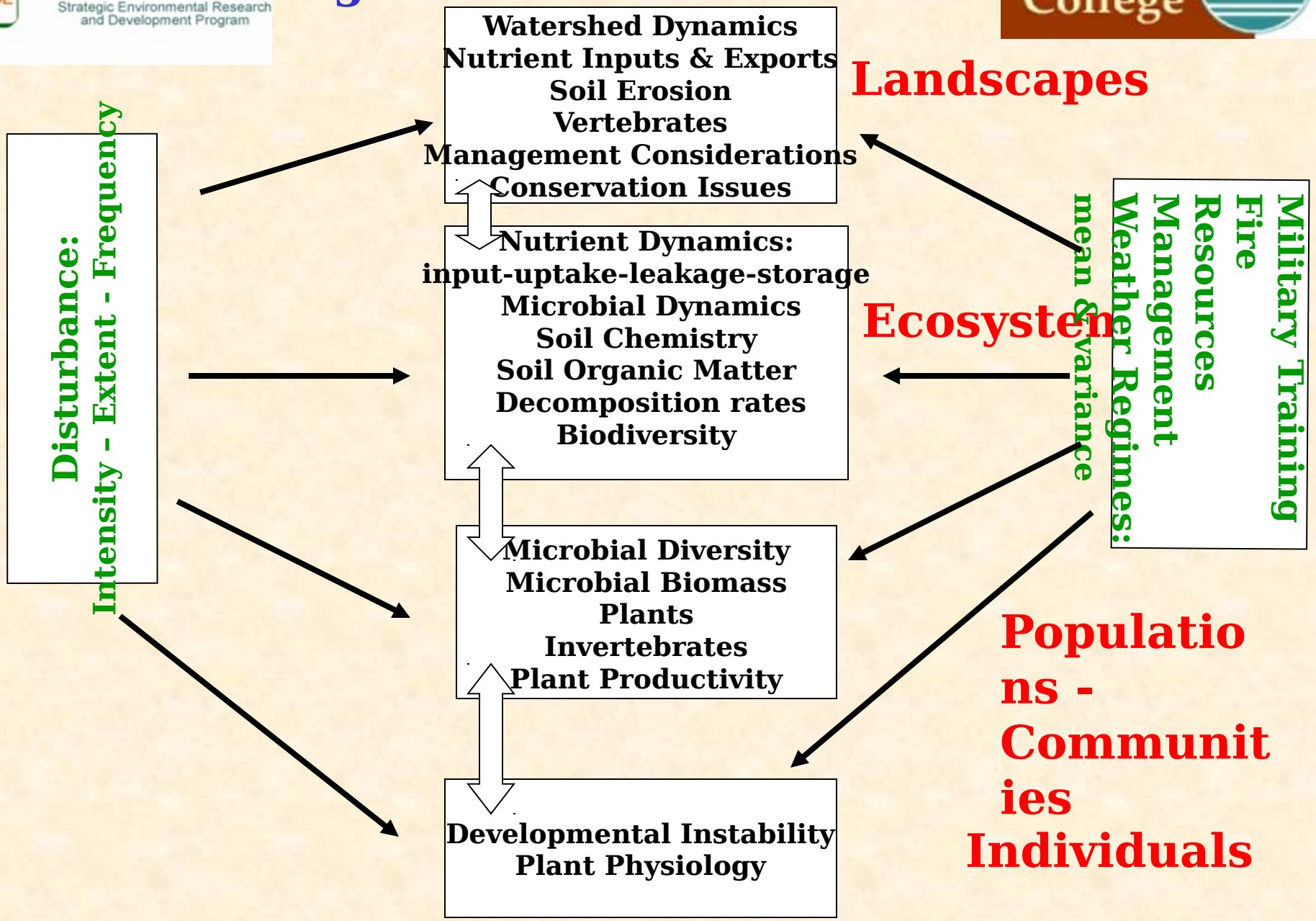
Low

No military vehicles
Minimal foot traffic

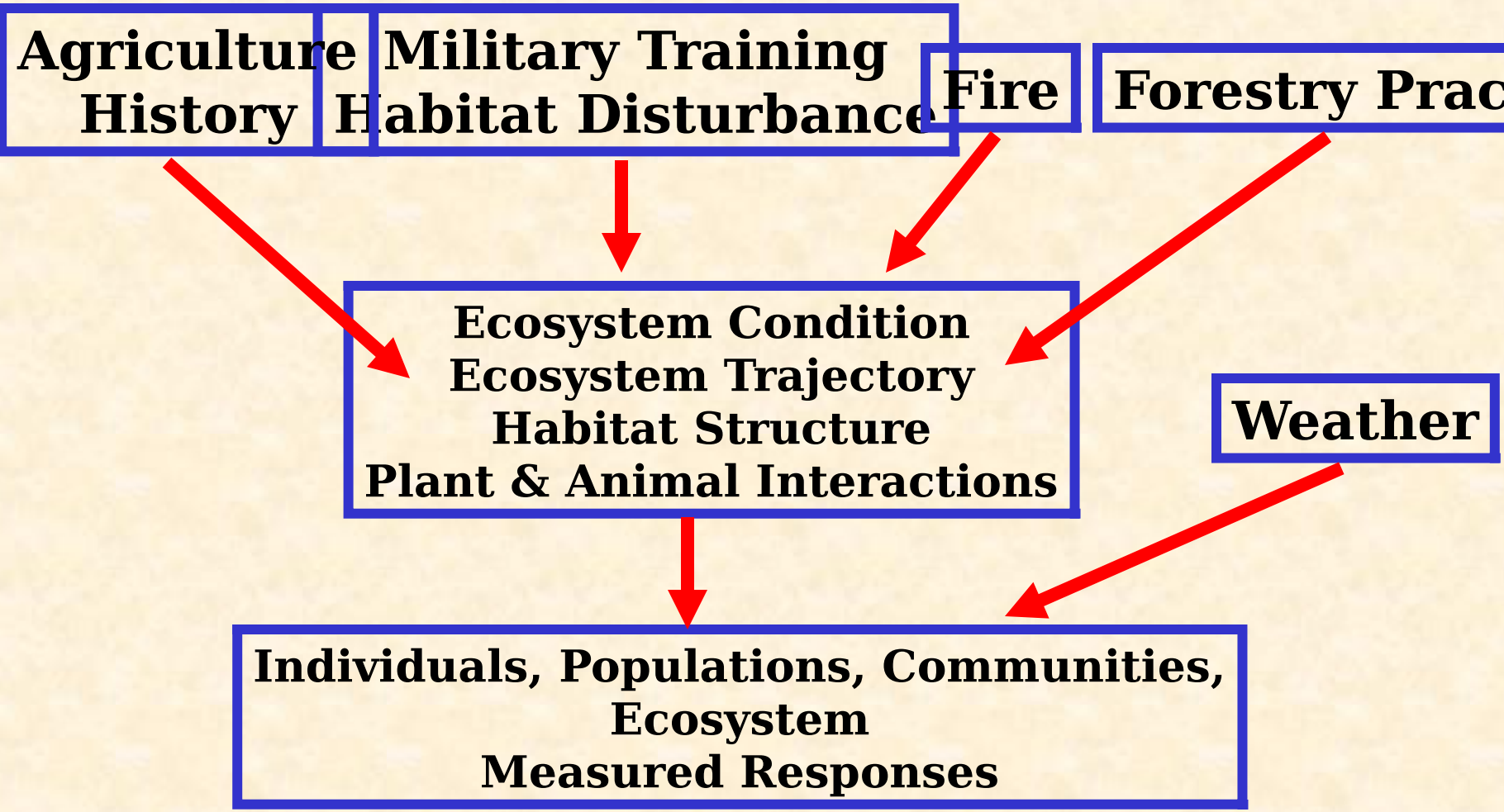
L2

L1

Ecological Hierarchical Processes



Disturbance to Ecological Systems are Complex



Research Approach

- **Select Ecological Indicator Systems (EISs)**
  - **Based on Individual, Population, Community, and Ecosystem Parameters**
  - **Experience/Expertise of PIs & Literature**
  - **Measure Responses To:**
    Ecological Processes, Structure/Composition, Physiology
- **Develop Ecological Indicator Guilds (EIGs)**
  - **Discriminant Analysis of Each EISs with Respect to a Disjunct Landscape Disturbance Gradient**
- **Multivariate & Structural Equation Modeling**
  - **Associate Ecological Indicator Guilds along a Continuous Landscape Disturbance Gradient**
- **Identify Ecological Indicators**

Ecological Indicator Systems

- **Habitat Characterization**
  - **General Habitat**
  - **Ground Cover Plant Communities**
  - **Ground Cover Oak Seedling Communities**
  - **General Ground Cover**
- **Ground Ant Communities**
- **Microbial Communities**
- **Soil Chemistry**
- **Nutrient Leakage (using Lysimeters)**
- **Developmental Instability (DI)**

Ecological Indicator Guilds

Disturbance Classes Separated with ONE DF

EIS GC= ground cover	N original variables	Ecological Indicator Guild	Statistical Significance P =
Habitat	**15**	**2**	**0.001**
GC Plant C.	126	9	0.004
GC Oak C.	8	8	0.007
GC General	10	5	<0.001
Soil	6	6	<0.001

Ecological Indicator Guilds

Disturbance Classes Separated with TWO DFs

EIS	N original variables	Ecological Indicator Guild	Statistical Significance P =
Soil Chem. (Fall)	6	6	<0.001 0.001
Nutrient Leakage	12	7	<0.001 <0.001
Ground Ant Communi	28	6 (5)	<0.001 0.003 (0.009)

Ecological Indicator Guilds

Only HIGH Disturbance Class Separated

EIS	N original variables	Ecological Indicator Guild	Statistical Significance P =
Microbial Communities	**4**	**4**	**<0.001** **0.74**
Cnidoscolus stimulosus **DI**	**9**	**9**	**<0.001** **0.67**

Ecological Indicator Guilds

Disturbance Classes Could NOT be Separated

EIS	N original variables	Ecological Indicator Guild	Statistical Significance P =
Tree Communities	48	0	
Rhus copallinum DI	12	0	

Habitat Ecological Indicator System

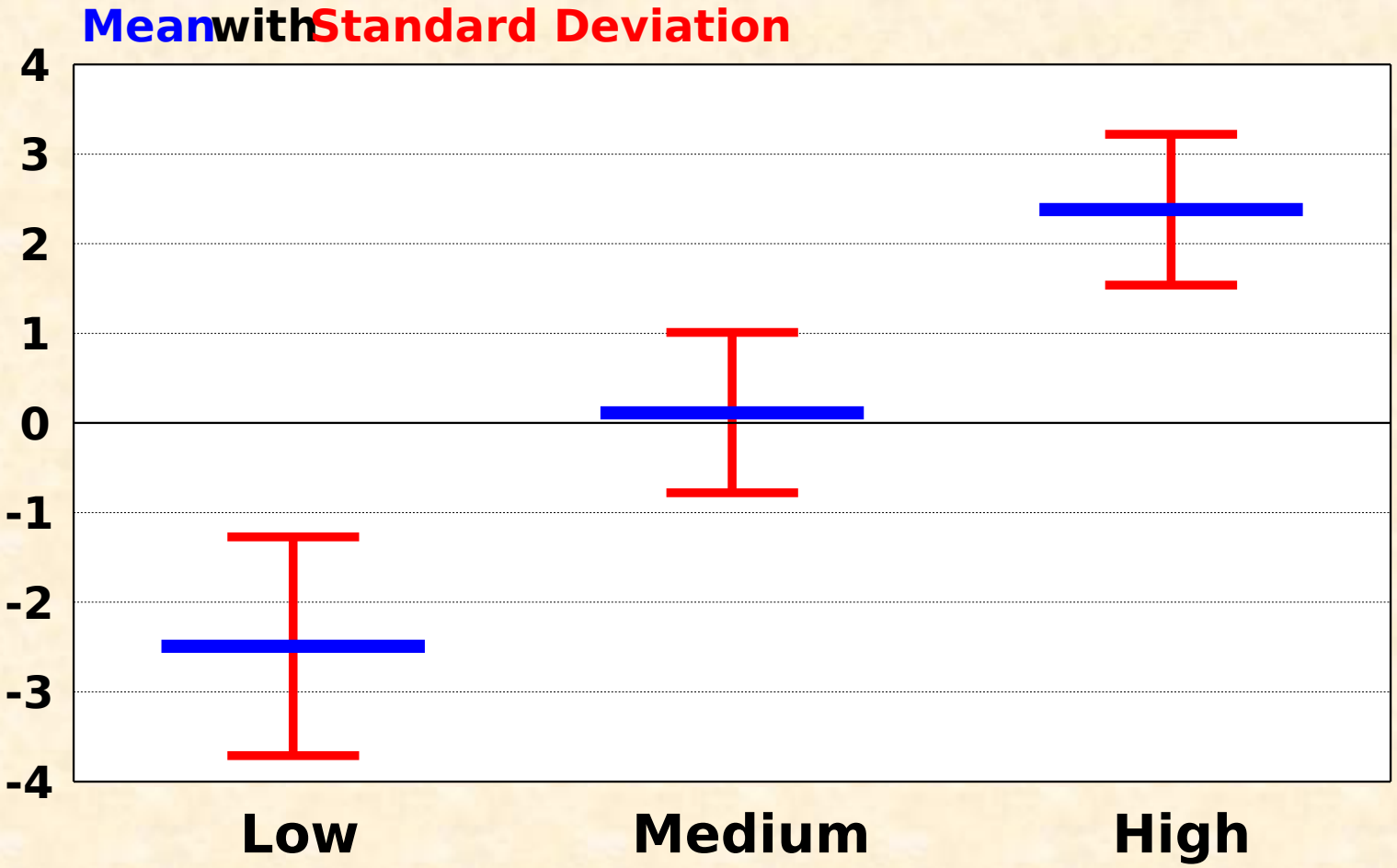
15 Variables

- A-Horizon Depth
- Soil Compaction
- Soil Shear Stress
- Bare Ground
- Forb Cover
- Grass Cover
- Woody Cover
- Canopy Cover
- Tree Density
- Basal Area
- DBH
- NBAF5
- NBAF10
- NBAF20
- NBAF40

NBAF = number of trees from Cruz-All basal area facto

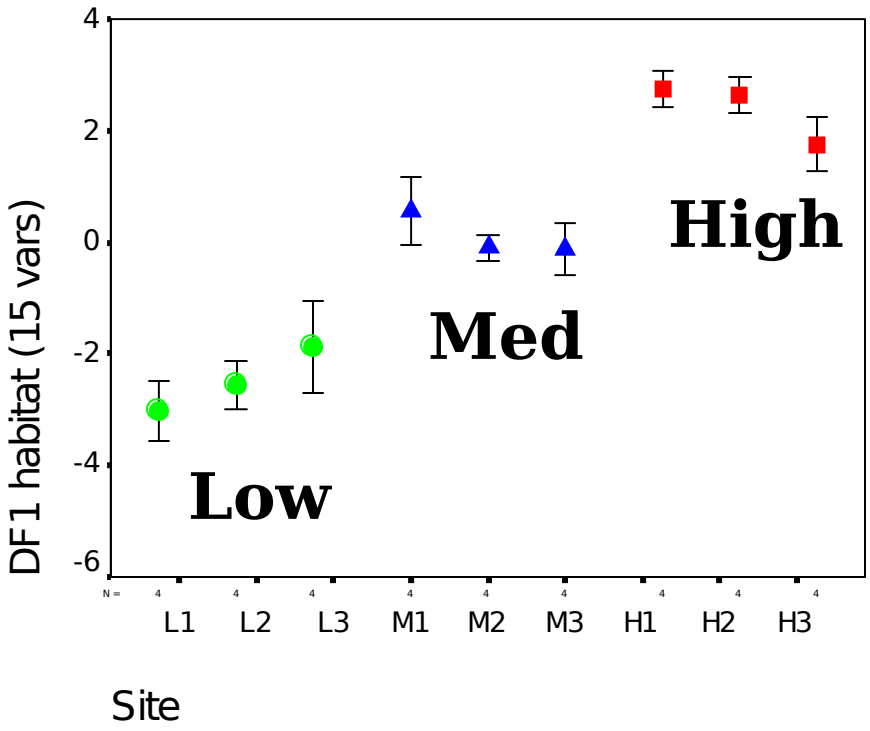
Habitat EIS DF1

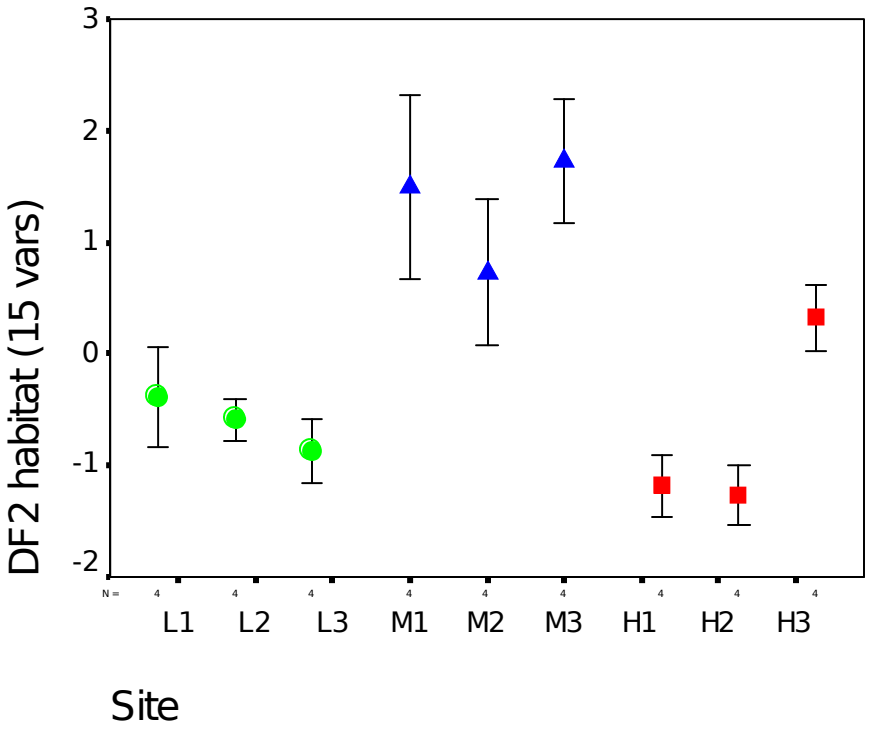
(15 Habitat Variables)



Habitat EIS

15 Habitat Variables





DF1

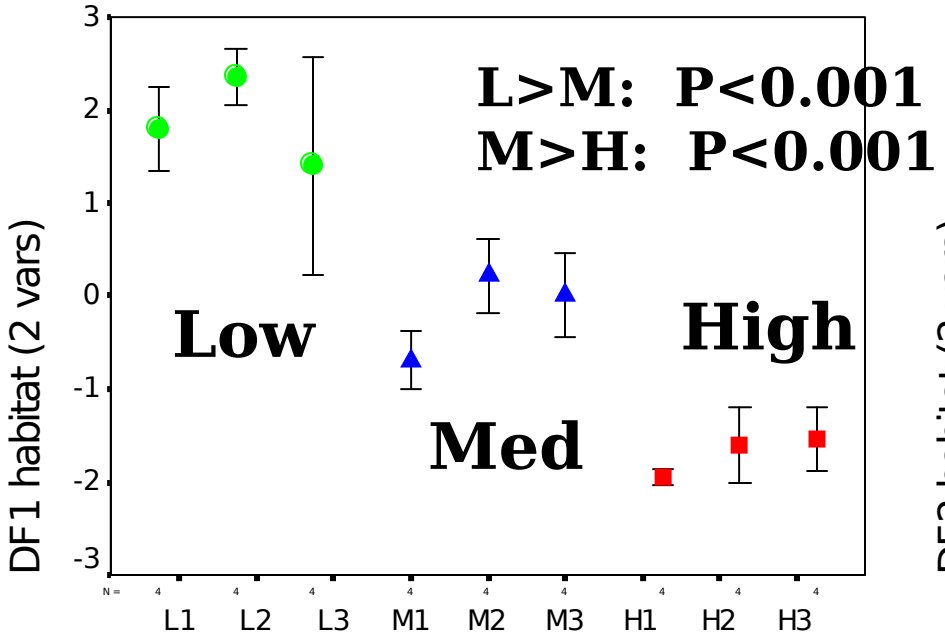
Mean with SE

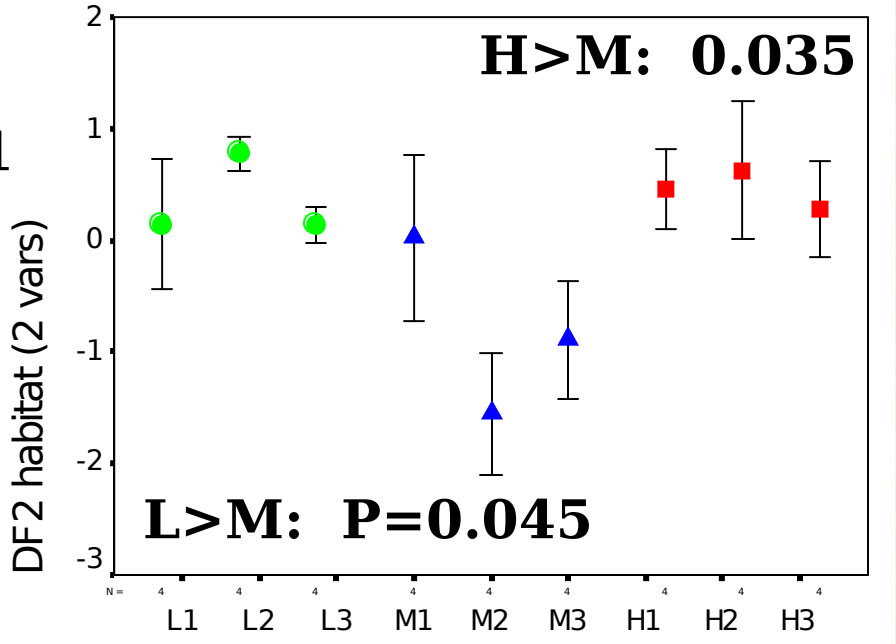
DF2

Mean with SE

Habitat EIG

A-Horizon Depth & Soil Compaction





DF1

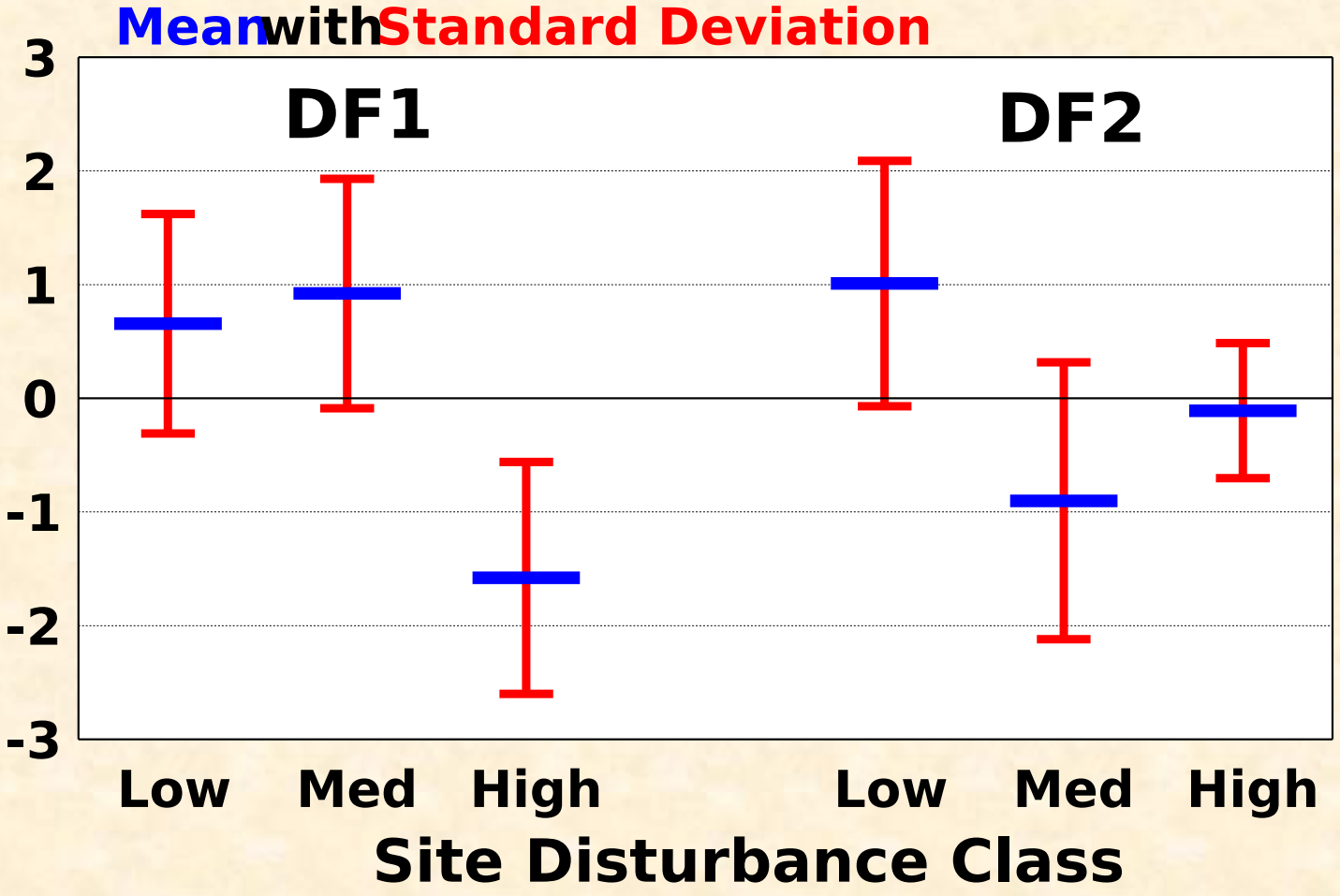
Mean with SE

DF2

Mean with SE

Ground Ant Communities EIS

28 Species

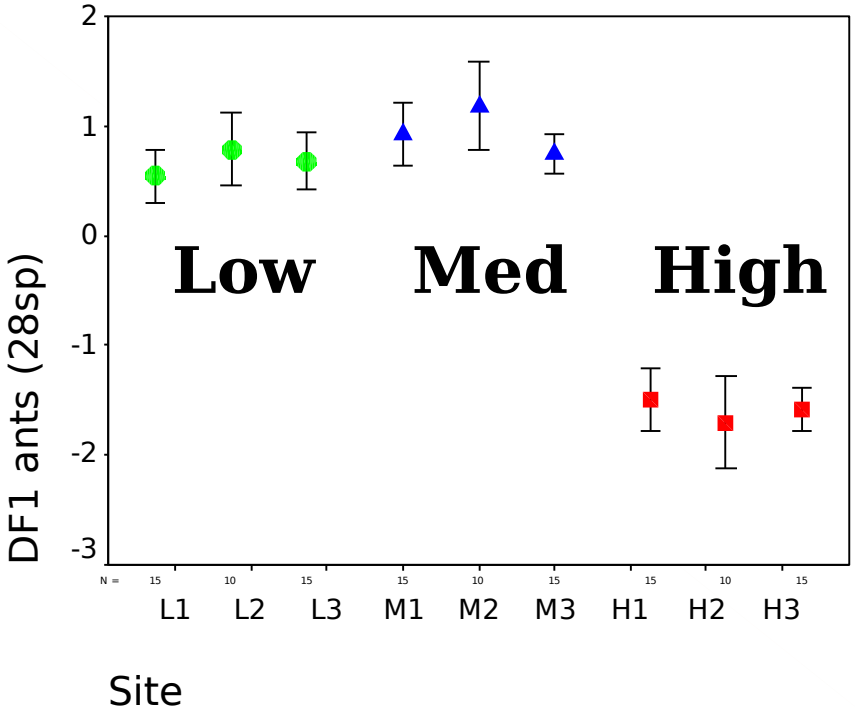


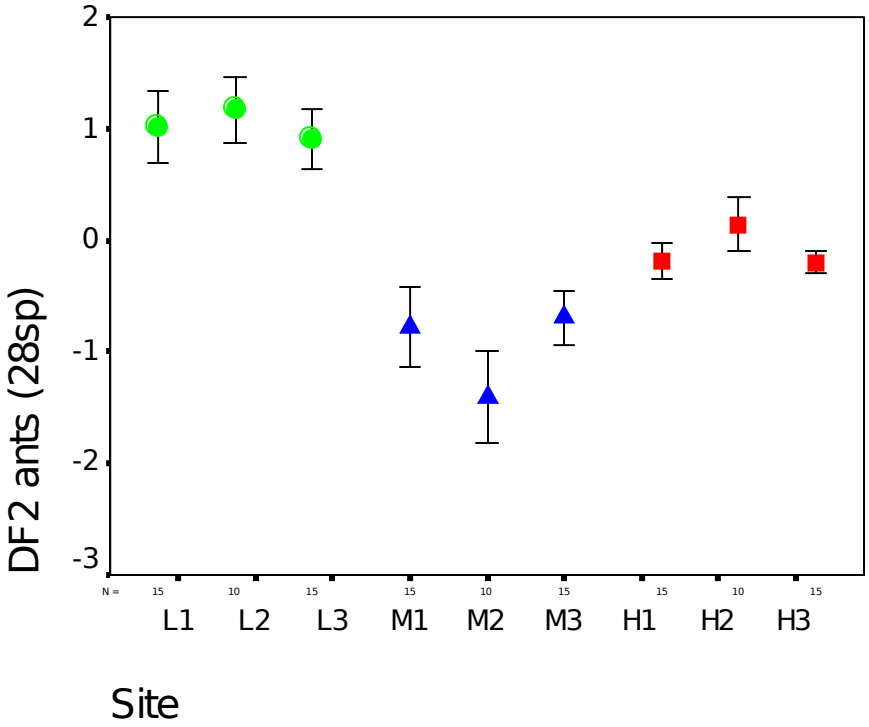
Ant Communities EIG

2000, 2001, 2002 Pit-Fall Traps

28 Species, N=103,203

Dorymyrmex smithi = 87% of individuals





DF1

Mean with SE

DF2

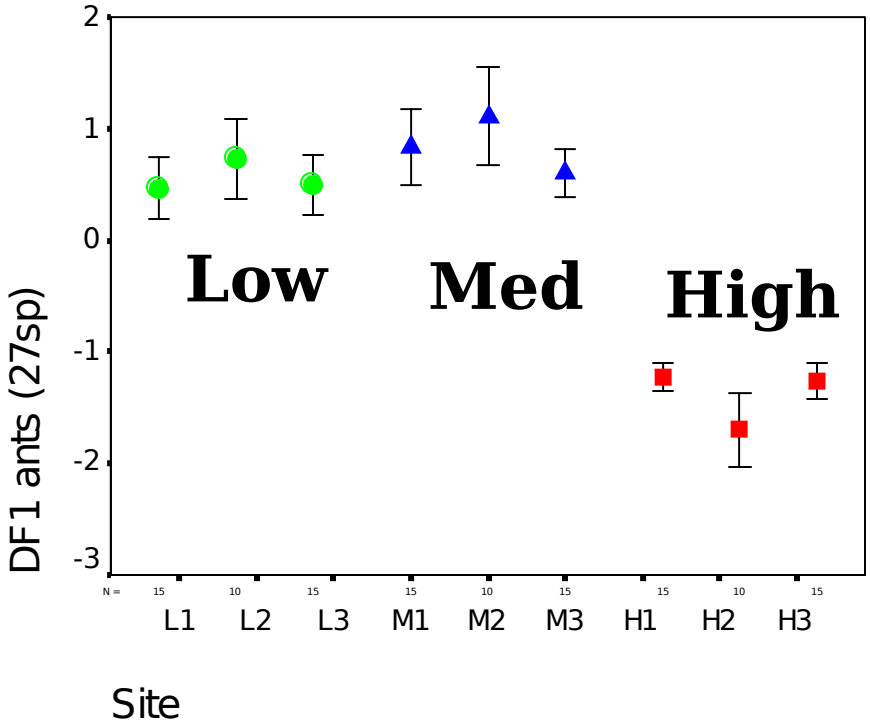
Mean with SE

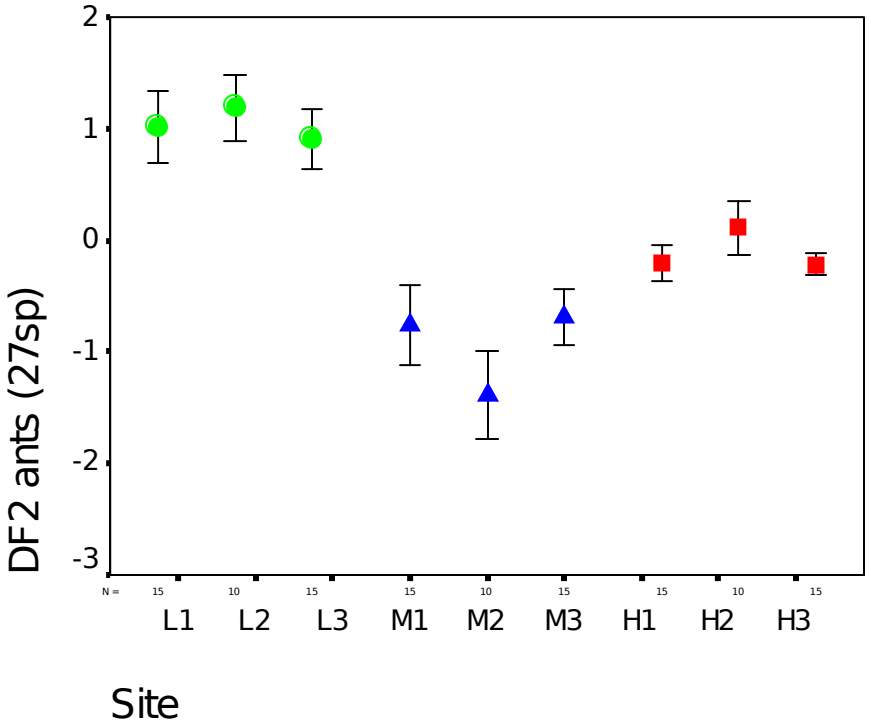
Ant Communities EIG

2000, 2001, 2002 Pit-Fall Traps

27 Species, N=13,774

Dorymyrmex smithi deleted from analysis





DF1

Mean with SE

DF2

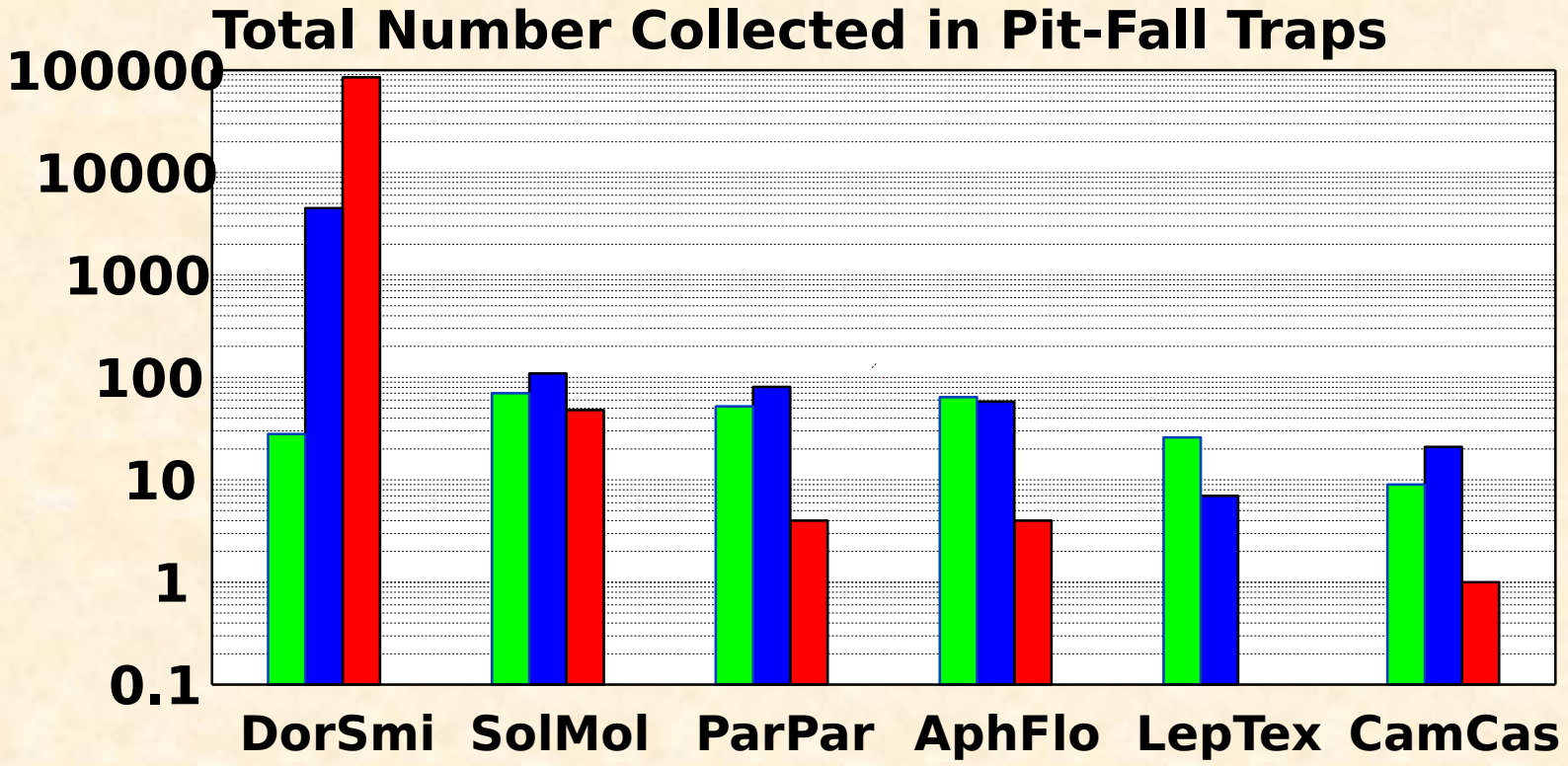
Mean with SE

Ground Ant Communities Ecological Indicator Guild
(reduced from 28 original species)

	(Abundance Rank)	N
Dorymyrmex smithi	(1)	(89429)
Solenopsis molesta	(9)	(227)
Paratrechina parvula	(12)	(137)
Aphaenogaster floridana	(13)	(126)
Leptothorax texana	(24)	(33)
Camponotus castaneus	(25)	(31)

Ant Ecological Indicator Guild

(2000-2001-2002)



Note LOG Scale

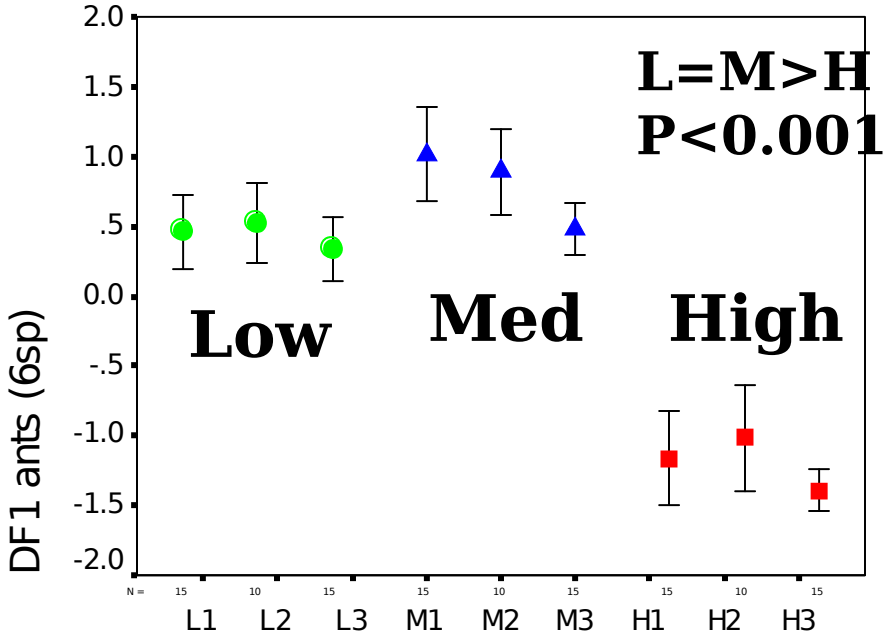
Ant Communities EIG

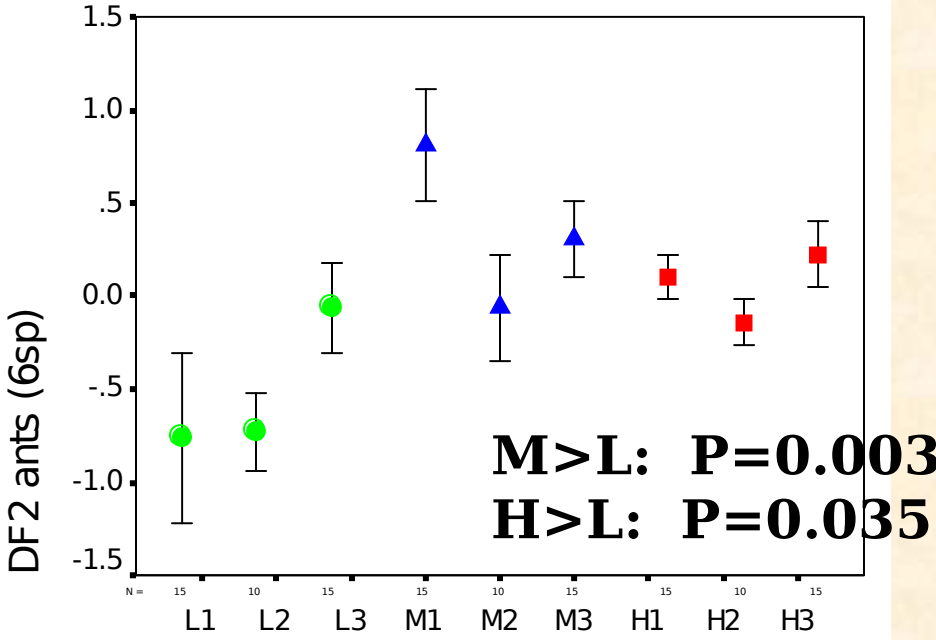
Based on Step-Wise Discriminant Analysis

2000, 2001, 2002 Pit-Fall Traps

6 Species, N=89983

Dorymyrmex smithi = 99% of individuals





DF1

Mean with SE

DF2

Mean with SE

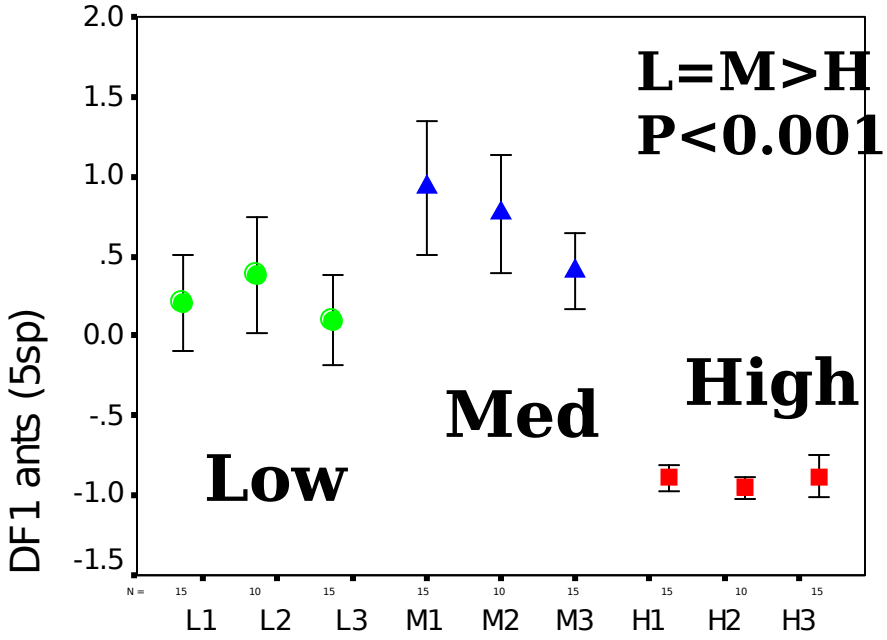
Ant Communities EIG

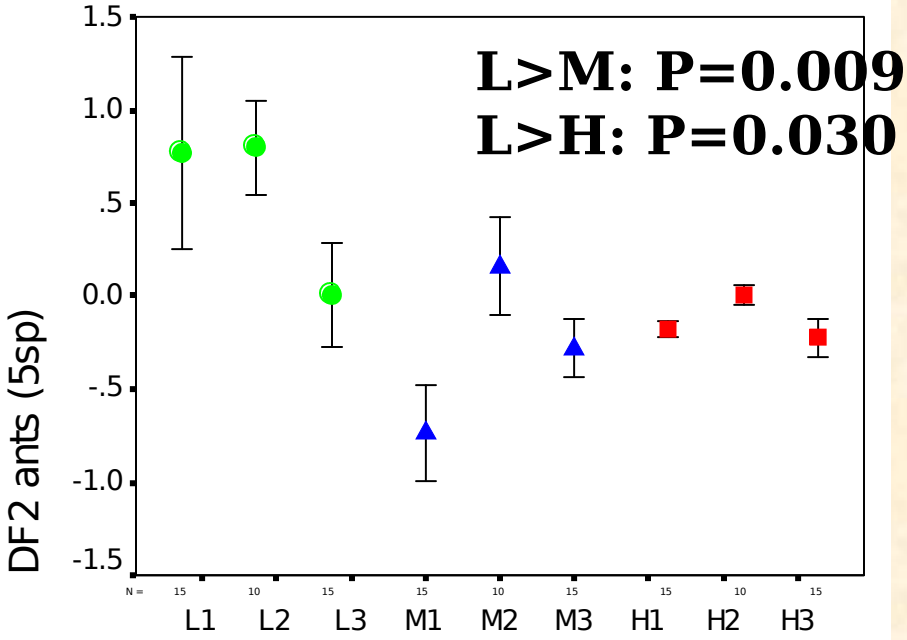
Based on Step-Wise Discriminant Analysis

2000, 2001, 2002 Pit-Fall Traps

5 Species, N=554, *Dorymyrmex smithi* deleted

0.54% of all individuals, 0.62% Step-Wise Individuals





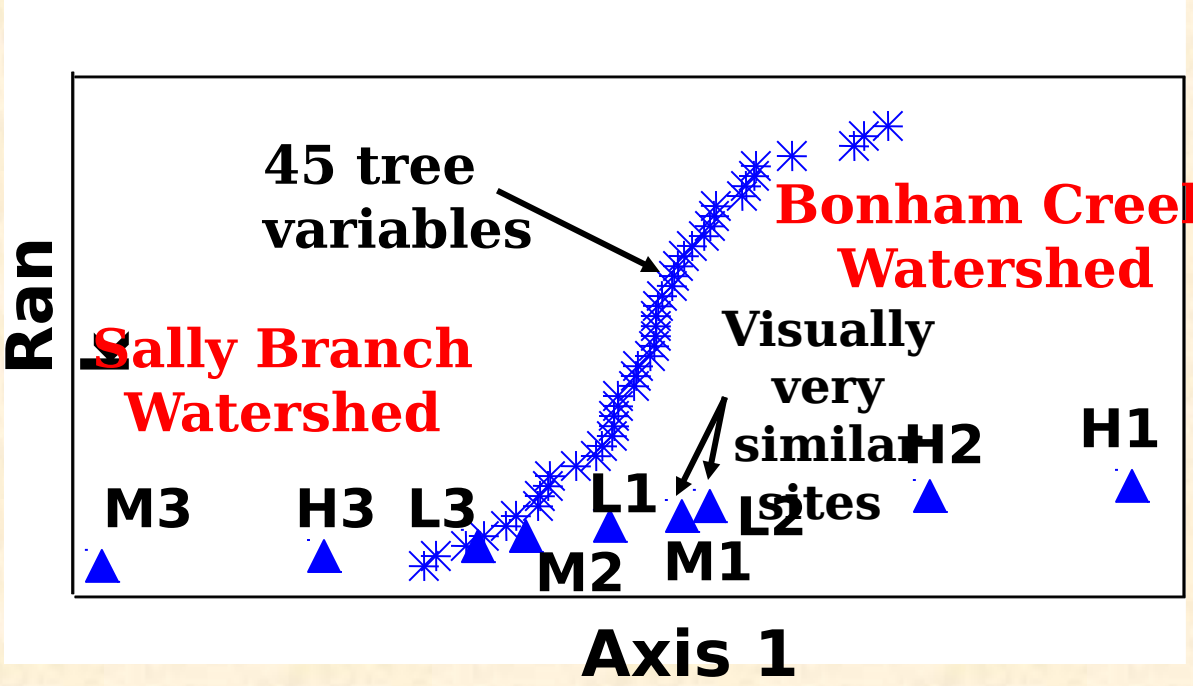
DF1

Mean with SE

DF2

Mean with SE

NMS Ordination Based on Tree Communities (Floristics)



15 Tree Species: density, mean DBH, std. dev. DBH

Conclusions

- **The Guild Approach using Discriminant Analysis has been useful in identifying classes of variables or species that possess a similar response to a disjunct Landscape Disturbance Gradient, and therefore show promise as Ecological Indicators**
  - **Habitat metrics: particularly A-Horizon Depth and Soil Compaction, but also parameters of ground cover**
  - **Ground Ant Communities**
  - **Microbial Communities, Soil Chem., Nutrient Leakage, DI**
- **DA demonstrated to optimize/minimize sampling effort & costs**
- **Quantifies sampling effort versus desired accuracy**
- **Nonmetric Multidimensional Scaling (NMS) ordination shows excellent potential for identifying and ranking underlying community structure in a Landscape Disturbance Gradient**

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